10/049344
JC Rec'd PCT/PTO 11 FEB 2002

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Component Part Having a High Absorptive Effect over a Broad Frequency Range

The present invention relates to a lining or shape element for means of transportation. In the prior art, absorbers made of fibrous materials are known which are employed as non-woven components. In addition to natural fibers, polymeric fibers, inorganic or metallic fibers may be employed as said fibers. Bonding to the components is effected by bonding through intrinsic as well as extrinsic fibers and/or through a binder which may be of polymeric or even inorganic nature.

Further, absorbers made of open-pore foams of a polymeric, organic as well as inorganic material are known. The optimum absorption effect of such materials is within a frequency range of from 2000 to 10,000 Hz.

From the various fields of technology, the use of Helmholtz resonators having a wide variety of dimensions is known for the damping of air-borne sound; in the field of motor vehicle construction, reference may be made representatively to the German Offenlegungsschriften DE 196 15 917 A, DE 196 13 875 A and DE 37 29 765 A. These absorbers are very space-intensive and only conditionally suitable for motor vehicle construction.

DE 197 54 107 C1 and the prior art references cited therein, the full disclosure of which is included herein by reference, examine the absorptive behavior of microperforated components. The document mentioned examines baffle structures built of layers of microperforated plastic sheets pending from a ceiling or a roof as so-called compact absorbers. The microperforated plastic sheets are suitable for absorbing very effectively on one side or both sides thereof sound waves impinging from the space in a perpendicular, oblique or glancing direction, especially at higher frequencies.

If additionally, for every microperforated sheet, a further non-perforated sheet is spanned in parallel at a distance of some centimeters, the absorption of the acoustically active sheet is not improved. This is explained by the fact that the latter sheet needs neither a reverberant back wall nor a gap of any shape as an air cushion in between for displaying its damping activity. In contrast, if the microperforated sheets are replaced by non-perforated sheets of the same material, only a very low absorption remains. It is well-known that sound absorption arises for a resonator arrangement where a mass-spring effect can occur. A physical explanation for the sound absorption of the microperforated sheets is not considered possible by the inventors of the mentioned document.

Further, there are known microperforated sheets and plates which can filter out defined frequencies as a function of the pore diameter, the distance of the sheet from the wall, the surface area which is open due to the bores and the sheet thickness. DE 197 54 107 A describes such a sound absorber for the field of rooms. Here, the effect is seen that a high absorption can be achieved only over a relatively narrow frequency range. A broadening of the absorption range is always connected with a considerable loss of absorption and finally gets completely ineffective.

In a two-layer arrangement in which two sheets are arranged behind one another, two frequency ranges can be absorbed. Thus, a broadening is possible without reaching the broadness necessary in the automobile field.

Further, there are known structures where a sound-impermeable plastic sheet is provided with perforations in order to achieve an absorptive effect from the underlying absorber, see for example DE 30 18 072 A, DE 41 23 593 A.

DE 41 19 783 A describes a sound-absorbing element which consists of two perforated plates provided on top of one another, arranged at a distance from the substrate element and from each other. Between the two perforated plates, there is a foam plate. The perforated proportion of the sound-facing side is 50%, and that of the side facing away from the sound is 20% and thus clearly above the values considered necessary here.

It has been the object of the invention to provide an absorber which has an absorptive effect throughout the range of frequencies interesting to the automobile industry (from 500 Hz to 5000 Hz) and does not need much building space.

According to the invention, this object is achieved by providing a layered structure of microperforated absorbers and a non-woven material and/or foam absorber and/or air gap in such a way that a non-woven material and/or foam absorber and/or air gap alternates with a microperforated plate/sheet (microperforated sheet absorber). Preferably, the absorbers have such a structure that one or two microperforated plates/sheets are stacked in connection with two or three non-woven and/or foam absorbers or one or two gaps.

Due to the perforated design of the microperforated absorbers and the thickness of the non-woven and/or foam absorbers and/or air gaps, a coupling of the two kinds of absorbers is achieved. When the coupling of the individual absorber types is considered, a distinction must be made in terms of which type is provided on the surface in the direction of sound entry.

If a non-woven and/or foam absorber and/or air gap is positioned on the sound-facing side, the properties of the composite (microperforated plate/sheet - non-woven and/or foam absorber and/or air gap) are determined by the non-woven and/or foam absorber alone from a defined thickness. Depending on the kind of non-woven and/or foam absorber and/or air gap employed, this thickness is from 20 to 40 mm.

With decreasing thickness (from 40 mm to 0.3 mm) of the non-woven and/or foam absorber and/or air gap, the microperforated absorber increasingly contributes to the effect. By selecting the thickness of the non-woven and/or foam absorber and/or air gap, the effects of the two absorbers can be matched to one another. The same applies to a subsequent ply of microperforated absorber and non-woven and/or foam absorber and/or air gap for multilayered absorbers.

If the microperforated sheet absorber is positioned on the sound-facing side, coupling of the two types of absorbers can be effected primarily through the open

surface area. With increasing open surface area, the absorption behavior is increasingly determined by the non-woven and/or foam absorber and/or air gap. For an open surface area of about 40%, the non-woven and/or foam absorber and/or air gap reaches its full activity without the microperforated absorber completely losing its activity.

According to the invention, one or more microperforated sheet absorbers are layered with an open surface area of preferably up to 4%. On the surface on the sound-facing side and/or between the plates or between the wall and the last microperforated sheet resonator, there is a foam and/or non-woven absorber or air.

The absorption behavior of the absorber which represents the surface of the sound-facing side dominates the absorption behavior of the overall system.

Therefore, in the case where a foam and/or non-woven absorber is positioned on the surface, of course, the thickness of the absorber also plays a role. When a foam and/or non-woven absorber as used in the automobile field is positioned in the first ply towards the sound impingement, the effect of a microperforated sheet absorber positioned in the second layer as seen from the sound source is reduced from a thickness of about 7 mm of the foam and/or non-woven absorber to such a high extent that its effect can hardly be detected any more. In this case, the property picture of the foam/non-woven absorber dominates.

On the other hand, when the microperforated sheet absorber is positioned on the surface of the sound-facing side, it will dominate the property picture of the overall system. In this case, the effect of the foam and/or non-woven absorber and/or air gap is decidedly low, and its use is of no practical importance.

When the microperforated sheet absorber is positioned before the foam and/or non-woven absorber and/or air gap as seen from the sound source, the inclusion of additional open surface areas in the microperforated sheet absorber results in a coupling of the microperforated sheet absorber and foam and/or non-woven absorber and/or air gap.

If the open surface area is increased solely by increasing the number of holes while the hole diameters remain equal, i.e., the interhole distance decreases, then the properties of the overall system will change to the extent to which the properties of the microperforated sheet absorber change, i.e., after a maximum is passed, the effect strongly decreases.

However, if the open surface in the microperforated sheet absorber is increased by including additional holes having a surface area of from 6 mm^2 to 40,000 mm^2 (macroperforation), which do not exhibit any absorption effect for the given structure of the microperforated sheet absorber alone (wall distance, sheet thickness, interhole distance), there will be coupling to the foam and/or non-woven absorber.

In contrast to expectations, no simple superposition of the two effects was seen in such terms that one effect increases and the other decreases. Rather, there is a shift in the maximum absorption into a different frequency range, or two separate absorption maximums can be formed.

It is important in this connection that the frequency range audible to the human ear can be covered by this coupling of the two absorbers, which can never be achieved by a microperforated sheet absorber or a foam/non-woven sheet absorber alone for the given wall distance (from 10 to 20 mm).

It is important in this connection that, for a medium concentration of the holes for the microperforation, the arrangement of the holes on the total surface of the component does not codetermine the absorption ratio, as represented in Figure 3.

In Figures 3a) to c), the components have equal hole diameters and the same open surface area. For measurements in Kundt's tube, they yield almost the same absorption maximum at the same frequency.

On the one hand, this perforation can be utilized in a well-purposed manner for the design, especially in the areas which are in the visible region, for example, in the interior.

On the other hand, the areas of the microperforated sheet absorber which have only microperforation (no macroperforation) can be increased in surface area to obtain the same effect as if the macroperforation did not exist (high efficiency). Then, the macroperforation still yields the effect of the foam and/or non-woven absorber.

For the same open surface area, the effect of the microperforated sheet absorber is determined by the design of the open area. If an increase of the open area is achieved by an increase in the number of the microperforations, then the effect of the two absorber types is an optimum for each open surface area.

However, the preparation of such microperforated sheet absorbers is tedious so that an increase of the open surface area by increasing the holes up to a striate structure of the microperforated absorber and non-woven and/or foam absorber can also be employed simultaneously. The size of the open areas is within a range of from 6 to 40,000 mm^2.

To achieve a spatially homogeneous absorption, the contiguous open surface area must not exceed a value of 40,000 mm^2.

In the following, some typical structures as employed in the automobile field are represented.

The lining or shape elements according to the invention are suitable for replacing non-sound-absorbing lining or shape elements in the vehicle field as previously used in the prior art by sound-absorbing lining or shape elements. In addition, the present invention permits to design novel elements in the vehicle field which did not previously exist in the prior art.

Particularly preferred lining or shape elements according to the present invention include, for example, wheel housings, hoods, hood linings, engine encapsulations, heat transfer plates, vehicle shields, transmission tunnel linings, dashboards, vehicle seats, seat backs, armrests, steering wheels, carpetings, especially carpets,

roof linings, pillar linings, door linings, passenger compartment linings, luggage shelves, rear shelves, heat shields and/or trunk linings.

Ins. B4

Figure 1 shows a transmission tunnel lining which comprises different hole sizes in the microperforated sheet absorber. Figure 2 shows a roof lining designed by means of the present invention.

Ins. B5

Thus, using the present invention, it is possible to provide lining or shape elements for means of transportation which not only have a microperforated sheet absorber at a distance from the reverberant wall, but in addition several microperforated sheet absorbers on top of one another, respectively arranged at a certain distance between them.

The sound-technological properties of the lining or shape elements in the vehicle field according to the invention are essentially determined by the number of microperforated sheet absorbers, the proportion of hole area, the interhole distances and the hole diameters.

Therefore, particularly preferred according to the present invention are lining or shape elements in the vehicle field which are characterized in that said microperforated sheet absorber has a proportion of hole area with microperforation of from 0.2 to 4%, especially from 0.3 to 2%, based on the surface area of the microperforated sheet absorber. Of course, it is possible to design them respectively with a different or the same proportion of hole area. The holes can be introduced into the microperforated sheet absorber with any desired geometry by methods per se known in the prior art, for example, by punching or laser irradiation.

If the proportion of hole area is chosen too low, a sound-absorbing effect does not exist, or not sufficiently so, while on the other hand, when the proportion of hole area is chosen too high, the sound-absorbing effect again decreases.

Preferably, the lining or shape elements in the vehicle field according to the invention comprise holes in a microperforated sheet absorber having one or more diameters within a range of from 0.05 mm to 2 mm, especially 0.01 mm to

0.8 mm, and one or more interhole distances in the sheet absorber within a range of from 1 mm to 3 mm, especially from 2 mm to 20 mm.

The hole sizes or interhole distances in a second or in further subsequent microperforated sheet absorbers are on the same scale as in the first microperforated sheet absorber, but are distinguished by their absolute size.

Thus, for example, it is possible to design all the usual components of the interior of vehicles, especially those arranged before hollow spaces, in the microperforated configuration. For example, by laser irradiation, irreversible holes can be produced in all known materials.

To be able to have a sound-absorbing effect, it is preferred according to the present invention to provide the holes with a larger diameter, for example, within a range of from 0.5 mm to 2 mm, in the more remote visible area, for example, in the roof lining or rear shelf in motor vehicles, or in the roof lining or hand luggage shelf in planes. In the near region, which is especially perceived optically, it is preferred according to the present invention to provide holes having a diameter of from 0.05 to 0.5 mm. With holes having diameters within a range of from 0.3 to 0.1 mm diameter, the viewer does no longer optically perceive the holes in the surface or takes them for a structure. Thus, for example, vehicle seats, seat backs, armrests, side parts of the seats, dashboard and side and door linings can have microperforated surfaces according to the present invention.

In the engine compartment, many parts are arranged before hollow spaces, wherein the hollow spaces need not be enclosed. The heat shields above the exhaust manifolds and other hot parts of the engine may also have a microperforated design. Also, it is possible to provide virtually the complete interior lining of the engine compartment, such as engine encapsulations or hood linings, with the microperforated design. When surfaces of the vehicle or engine are directly equipped according to the present invention, a particularly good sound absorption can possibly be achieved at the site of sound development.

It is well known that the mutual wall distance between the sheet absorbers affects the sound-absorption capability. In a preferred embodiment of the present invention, the mutual distance of the microperforated sheet absorbers is constant when more than 2 microperforated sheet absorbers are present. Thus, these are parallel, optionally plane-parallel, layers. Since plane-parallelity is usually undesirable in vehicle construction, in a further preferred embodiment of the present invention, the mutual distance of the microperforated sheet absorbers is varying when more than 2 microperforated sheet absorbers are present. Further, this is to be understood in such terms that, for example, curved, convex or concave layers having different radii of curvature are facing each other.

According to the present invention, it is not necessarily required that the space between the respective microperforated sheet absorbers is filled with a damping material. In the case where a damping material is present, the latter is more preferably selected from open-pore foams, especially of plastic or metal, and of a non-woven material. It is possible to fill the distance or the respective distances between the microperforated sheet absorbers in part or completely with the desired material.

Thus, using the present invention, it is possible to provide lining or shape elements for vehicles, especially motor vehicles, for example, passenger cars, trucks, busses, motor bikes, track-bound vehicles, especially locomotive engines, waggons and streetcars, and for vessels and airplanes.